

Appendix A

Changes and Additions to the Vegetation Sampling and Analysis Plan, Fugitive Dust Study, Red Dog Mine, Alaska

Changes and Additions to the Vegetation Sampling and Analysis Plan Fugitive Dust Study, Red Dog Mine, Alaska

Sample Collection

- Exact coordinates of sampling locations differed slightly, and occasionally significantly, from the coordinates reported in the vegetation sampling and analysis plan (Exponent 2001). For example, transect 5 was shifted about 450 m south of the original location, from a region with very little *H. splendens* to one with more abundant moss. Four alternate port site locations were selected in the field, because the original sites were inaccessible or had no moss. The original coordinates for HR-06-04 and HR-07-04 fell on ridges with very little vegetation, so new sites were chosen from the air and were located as close to the originals as feasible.
- As described in the sampling plan, forage species were chosen in the field based on availability, ecological significance, and subsistence use. These included *Peltigera aphthosa* (lichen), *Salix pulchra* (willow), and *Rubus chamaemorus* (salmonberry or cloudberry).
- In total, 50 moss samples, 13 willow samples, 12 lichen samples, and 7 berry samples were collected during the event (see Table A-1). Moss was collected at all designated sites except spill site 29, which did not have enough for a sample. In accordance with the sampling plan, willow samples were collected at all points along haul road transects 2, 3, and 7, and lichen was also collected at all four points along transect 7.
- *Peltigera aphthosa* and other lichen samples were rare at 3-m sites and uncommon at 10-m sites, so no other full transects of lichen were collected. Instead, lichen was collected where available, including samples from HR-01-02, HR-02-02, HR-02-03, HR-03-03, and HR-05-03.

- Salmonberries tended to be more common along the road than away from it, and samples were collected at 3-m and 100-m sites along haul road transects 1 and 4. However, there were not enough berries at 1,000-m sites to complete the transects. Salmonberries were also scarce at transects 6 and 7, so no berry collections were made at transects closest to the mine.
- Due to changes made to the sampling plan while sampling was occurring, three samples each of willow, lichen, and salmonberries were collected at the port, rather than the four samples of each species recommended in the plan.
- The sampling plan does not describe vegetation collection methods in detail. *Hylocomium splendens* (moss) and *Peltigera aphthosa* (lichen) samples were collected by hand using powderless latex gloves and stored in labeled, gallon-size Ziploc[®] storage bags. *Salix pulchra* (willow) branches were clipped with stainless steel scissors and stored in labeled Ziploc[®] storage bags. Ripe *Rubus chamaemorus* berries (salmonberries) were collected by hand using powderless latex gloves and deposited directly into pre-cleaned, labeled 8-ounce glass jars. Berry samples from HR-01-01 and HR-04-02 began to mildew after a few days on ice, so HR-01-01-B was replaced with a new collection from the same site, and all berry samples were frozen until shipment to slow decomposition. A second berry collection was attempted at HR-04-02, but plants had turned brown, and there were too few ripe berries left to take a sample.

Sample Processing, Storage, and Shipping

- The following precautions were taken to avoid sample contamination in the processing (clean) tent: At the onset of sample processing, the floor of the clean tent was swept and the interior walls wiped down with damp paper towels. Sample coolers were washed out with 1 percent Alconox solution and tap water, and all chairs, tables, and cooler exteriors were washed with Alconox and rinsed before they were moved into the clean tent. At the beginning of each day of processing, tables were wiped down with 1 percent Alconox solution and rinse water and covered with fresh paper, and the tarp beneath the tables was also wiped down with damp paper towels. At least two Whatman 41 paper filters were hung

inside the tent each day to monitor ambient air dust levels. Field crew members wore boot covers at all times inside the processing tent and handled samples with powderless latex gloves. Unwrapped gloves and bags were stored in doubled Ziploc[®] bags.

- *Hylocomium splendens* samples were processed in the clean tent using methods similar to those adopted by the National Park Service (NPS) in its studies. Before beginning the sampling effort, training on the NPS methods was provided to the sampling team by Brett Wolk, who had previously worked on the NPS program. One deviation from the NPS methods is that samples were not dried in the field prior to shipping. Essentially, moss samples were processed in plastic bowls using stainless steel forceps and powderless latex gloves. The moss was picked clean of debris, and clumps of mud were removed from the moss using forceps, although samples were not washed or dusted off. The last 3 to 5 years' of moss growth was clipped with forceps and saved for analysis.
- Lichen and willow samples were processed similarly. Plant material, clumps of dirt, and dead tissue were removed from lichen samples, but samples were not washed or dusted off. Willow leaves were removed from the stems by plucking the leaves at the base with forceps; stipules and buds were discarded. Green leaves were selected whenever possible, though willow leaves were turning yellow both on trees and in the Ziploc[®] bags over the course of the sampling event. Between samples, bowls and forceps were washed with 1 percent Alconox, rinsed with tap water, rinsed again with deionized water, and dried with paper towels. Fresh gloves were used for every sample.
- Moss, willow, and lichen samples from the haul road, port area, and spill sites were all double bagged, labeled, logged into a field notebook, and stored in coolers on blue ice until shipment. Unprocessed moss samples from the mine site were stored on blue ice and transported back to Exponent's Bellevue office, where they were processed in a clean environment using NPS methods. To ease future identification of specimens, voucher samples were saved for all moss, willow, and lichen samples.

Reference

Exponent. 2001. Vegetation sampling and analysis plan, haul road fugitive dust study. Prepared for Teck Cominco Alaska Inc., Anchorage, AK. Exponent, Bellevue, WA.

Tables

Table A-1. Summary of vegetation sampling for the haul road fugitive dust study

Area	Number of Sample Transects (or grid locations)	Number of Locations per Transect	Number of Samples				Analytes	
			<i>Hylocomium</i>	Willow	Lichen	Berry	<i>Hylocomium</i>	All Other Plant Species
Haul Road								
Transects corresponding to road stations	7	3, except for 3 transects near mine site where there will be 4 locations	23 + 2 field duplicates	10	9	4	As, Pb, Zn, Cd, Ca, Al, Fe, Mg	Pb, Zn, Cd, Ca
Port Site	14	1	14 + 1 field duplicate	3	3	3	Pb, Zn, Cd, Ca	Pb, Zn, Cd, Ca
Spill Sites	10	1	9 + 1 field duplicate	0	0	0	Pb, Zn, Cd, Ca	N/A
Total Number (including duplicates)			50	13	12	7		

Appendix B

Summary Statistics for Analytical Samples Results

Table B-1. Summary statistics for road surface samples

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Grain Density	g/cc	dry	11	11	2.68	2.7	2.72			
Grain-size Determination										
>15 μm	%	dry	10	10	71.6	82.99	88.55			
10–15 μm	%	dry	10	10	1.61	2.59	4.05			
5–10 μm	%	dry	10	10	3.62	5.47	9.75			
1–5 μm	%	dry	10	10	4.63	7.38	12.24			
0.375–1 μm	%	dry	10	10	1.15	1.57	2.37			
Metals										
Aluminum	mg/kg	dry	10	10	1,240	7,800	12,100			
Arsenic	mg/kg	dry	37	37	1.7	6.3	18.4			
Cadmium	mg/kg	dry	37	36	1.2	5.5	39.3	1	1	1
Calcium	mg/kg	dry	10	10	9,900	35,400	95,400			
Iron	mg/kg	dry	10	10	2,650	20,400	29,000			
Lead	mg/kg	dry	37	37	30.3	250	1,180			
Magnesium	mg/kg	dry	10	10	4,360	15,700	48,900			
Zinc	mg/kg	dry	37	37	185	940	6,610			

Table B-2. Summary statistics for road core samples

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals										
Aluminum	mg/kg	dry	1	1	12,100	12,100	12,100			
Arsenic	mg/kg	dry	29	28	1.3	11.3	32	1	1	1
Cadmium	mg/kg	dry	29	15	1	1.83	5.1	1	1	1
Calcium	mg/kg	dry	1	1	7,320	7,320	7,320			
Iron	mg/kg	dry	1	1	25,900	25,900	25,900			
Lead	mg/kg	dry	29	27	3.8	50	200	9.4	9.9	10.3
Magnesium	mg/kg	dry	1	1	8,010	8,010	8,010			
Zinc	mg/kg	dry	29	29	26.5	215	970			

Table B-3. Summary statistics for road core samples, 0–4 in.

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals										
Aluminum	mg/kg	dry	1	1	12,100	12,100	12,100			
Arsenic	mg/kg	dry	10	10	1.3	8.4	28.2			
Cadmium	mg/kg	dry	10	7	1.2	1.85	3.8	1	1	1
Calcium	mg/kg	dry	1	1	7,320	7,320	7,320			
Iron	mg/kg	dry	1	1	25,900	25,900	25,900			
Lead	mg/kg	dry	10	10	13.5	76	200			
Magnesium	mg/kg	dry	1	1	8,010	8,010	8,010			
Zinc	mg/kg	dry	10	10	90	292	566			

Table B-4. Summary statistics for road core samples, 4–8 in.

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals										
Arsenic	mg/kg	dry	10	9	2.4	11.1	29.9	1	1	1
Cadmium	mg/kg	dry	10	6	1	1.93	5.1	1	1	1
Lead	mg/kg	dry	10	9	4.4	49	121	9.4	9.4	9.4
Zinc	mg/kg	dry	10	10	42.2	247	970			

Table B-5. Summary statistics for road core samples, 8–12 in.

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals										
Arsenic	mg/kg	dry	9	9	2.4	14.7	32			
Cadmium	mg/kg	dry	9	2	1.3	1.43	1.55	1	1	1
Lead	mg/kg	dry	9	8	3.8	20.2	61	10.3	10.3	10.3
Zinc	mg/kg	dry	9	9	26.5	92	264			

Table B-6. Summary statistics for road shoulder fines

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Grain Density	g/cc	dry	2	2	2.69	2.7	2.71			
Grain-size Determination										
>15 μm	%	dry	10	10	47.16	74.26	89.81			
10–15 μm	%	dry	10	10	1.35	3.87	7.15			
5–10 μm	%	dry	10	10	3.4	8.3	17.15			
1–5 μm	%	dry	10	10	4.03	10.94	23.41			
0.375–1 μm	%	dry	10	10	0.92	2.63	5.12			
Metals										
Aluminum	mg/kg	dry	10	10	2,490	7,500	16,600			
Arsenic	mg/kg	dry	10	10	3.6	8.8	28			
Cadmium	mg/kg	dry	10	10	3.75	11.4	29.3			
Calcium	mg/kg	dry	10	10	11,500	38,000	82,200			
Iron	mg/kg	dry	10	10	5,010	19,200	27,600			
Lead	mg/kg	dry	10	10	116	610	2,440			
Magnesium	mg/kg	dry	10	10	6,130	19,700	41,000			
Zinc	mg/kg	dry	10	10	565	2,050	4,910			

Table B-7. Summary statistics for material sites soil samples

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals										
Aluminum	mg/kg	dry	6	6	2,110	6,600	12,400			
Arsenic	mg/kg	dry	6	6	2.9	9.5	20.2			
Cadmium	mg/kg	dry	6	3	1.1	1.9	3.3	1	1	1
Calcium	mg/kg	dry	6	6	2,550	32,100	96,100			
Iron	mg/kg	dry	6	6	5,300	21,700	37,300			
Lead	mg/kg	dry	6	6	8.6	24.4	36.9			
Magnesium	mg/kg	dry	6	6	1,090	17,100	49,700			
Zinc	mg/kg	dry	6	6	87.4	129	199			

Table B-8. Summary statistics for material sites surface water samples

Analyte	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals								
Aluminum	5	2	60.6	152	244	50	50	50
Arsenic	5	0				5	5	5
Cadmium	5	0				5	5	5
Calcium	5	5	19,300	91,000	286,000			
Iron	5	0				35.0	116	333
Lead	5	0				2	2.06	2.2
Magnesium	5	5	4,850	38,000	136,000			
Zinc	5	0				10	45.7	78

Note: All results reported in $\mu\text{g/L}$, unfiltered.

Table B-9. Summary statistics for dustfall samples

Analyte	Number of Analyses	Number of Detected Values	Deposition (mg dry wt)						Deposition Rates ($\mu\text{g}/\text{m}^2/\text{day}$ dry wt)		
			Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value	Minimum Detected Value	Mean Detected Value	Maximum Detected Value
Conventional Parameter											
Sample mass	27	27	25.7	250	579				41.6	405	937
Metals											
Aluminum	27	27	0.153	2.06	6.53				248	3,330	10,600
Arsenic	27	25	0.0002	0.002	0.0057	0.0001	0.0002	0.0003	0.324	3.24	9.23
Cadmium	27	26	0.0005	0.0047	0.0225	0.0003	0.0003	0.0003	0.809	7.61	36.4
Calcium	27	27	1.87	14	56.1				3,027	22,700	90,800
Iron	27	27	0.53	4.8	17.8				858	7,770	28,800
Lead	27	27	0.0129	0.132	0.526				20.9	214	851
Magnesium	27	27	0.766	6.6	27.6				1,240	10,700	44,700
Zinc	27	27	0.0339	0.77	3.85				54.9	1,250	6,230

Note: Samples were collected from August 22 to September 21 (30 days) in collectors with a diameter of 0.0206 m.

Deposition rates were calculated using detected values.

Table B-10. Summary statistics for moss (*Hylocomium splendens*) samples

Analyte	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals								
Aluminum	35	35	196	9,800	47,900			
Arsenic	35	30	0.234	4.3	15.7	0.2	0.2	0.2
Cadmium	60	60	0.501	10	48.4			
Calcium	60	60	1,760	24,000	117,000			
Iron	35	35	152	6,200	30,900			
Lead	60	60	9.54	360	1670			
Magnesium	35	35	590	10,200	63,400			
Zinc	60	60	59.2	1,320	6,480			

Note: All results reported in mg/kg, dry weight.

Summary statistics include haul road transects, spill sites, and port site samples.

Table B-11. Summary statistics for lichen (*Peltigera aphthosa*) samples

Analyte	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals								
Cadmium	12	12	0.259	4.40	11.9			
Calcium	12	12	1,070	3,700	11,000			
Lead	12	12	6.86	187	660			
Zinc	12	12	82.2	720	1,720			

Note: All results reported in mg/kg, dry weight.

Summary statistics include haul road transects and port site samples.

Table B-12. Summary statistics for willow (*Salix pulchra*) samples

Analyte	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals								
Cadmium	13	13	0.499	2.51	7.75			
Calcium	13	13	3,730	8,300	15,900			
Lead	13	13	0.431	10.5	45.6			
Zinc	13	13	122	210	546			

Note: All results reported in mg/kg, dry weight.

Summary statistics include haul road transects and port site samples.

Table B-13. Summary statistics for salmonberry (*Rubus chamaemorus*) samples

Analyte	Concentration Units	Measurement Basis	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Conventional Parameter										
Dry weight of tissue	%	dry	7	7	11.5	13.1	16.4			
Metals										
Cadmium	mg/kg	dry	7	7	0.0581	0.49	1.58			
	mg/kg	wet	7	7	0.00685	0.064	0.207			
Calcium	mg/kg	dry	7	7	680	1,690	4,220			
	mg/kg	wet	7	7	89.2	211	485			
Lead	mg/kg	dry	7	7	0.462	3	13.5			
	mg/kg	wet	7	7	0.0545	0.39	1.77			
Zinc	mg/kg	dry	7	7	15.8	30.5	70.5			
	mg/kg	wet	7	7	1.86	3.98	9.24			

Note: Summary statistics include haul road transects and port site samples.

Table B-14. Summary statistics for surface water samples

Analyte	Number of Analyses	Number of Detected Values	Minimum Detected Value	Mean Detected Value	Maximum Detected Value	Minimum Undetected Value	Mean Undetected Value	Maximum Undetected Value
Metals								
Aluminum	89	24	20.2	49	357	20	20	20
Cadmium	89	3	0.1	0.1	0.2	0.1	0.1	0.1
Calcium	89	89	6,250	27,000	64,600			
Iron	89	55	24.5	210	1,310	20	41	50
Lead	89	16	0.05	0.38	2.37	0.04	0.4	0.4
Magnesium	89	89	2,320	5,000	9,580			
Zinc	89	14	2.07	7.5	34.4	2	3	10

Note: All results reported in $\mu\text{g/L}$, unfiltered.

Appendix C

Quality Assurance Review: Soil, Water, Dust, and Vegetation Sampling

Quality Assurance Review: Soil, Water, Dust, and Vegetation Sampling

Introduction

A quality assurance review was completed by Exponent for metals and grain size analyses in soil, surface water, dust, and vegetation samples collected during the Haul Road Fugitive Dust Study at the Red Dog Mine, Alaska site. Samples were collected from July 11 to October 18, 2001. A modified U.S. Environmental Protection Agency Level 3 data validation was completed.

Analyses of metals in soil, water, and dust were performed by Columbia Analytical Services, Inc., Kelso, Washington. Additional analyses of metals in water were performed by CT & E Environmental Services, Inc., Anchorage, Alaska. Analyses of metals in vegetation were performed by Battelle Marine Sciences Laboratory, Sequim, Washington. Analyses of grain size were performed by PTS Laboratories, Inc., Santa Fe Springs, California.

Completeness

Results reported by the laboratory were 100-percent complete.

Holding Times and Sample Preservation

Holding time constraints were met for all samples.

Instrument Performance

The performance of the analytical instruments, as documented by the laboratory, was acceptable.

Initial and Continuing Calibration

Initial and continuing calibrations, as documented by the laboratory, were completed for all applicable target analytes and met the laboratory criteria for acceptable performance and frequency of analysis. There were no continuing calibration exceedances that resulted in sample qualification.

Initial and Continuing Calibration Blanks

The initial and continuing calibration blank analyses, as documented by the laboratory, met the laboratory criteria for acceptable performance.

Laboratory Blank Analyses

No analytes were detected in the laboratory blanks, with the following exception. Low levels of calcium, cadmium, iron, magnesium, lead, and zinc were detected in blanks associated with the vegetation analyses. None of the metals were detected at concentrations which required qualification of sample data.

Graphite Furnace Atomic Absorption Quality Control Checks

One graphite furnace atomic absorption spectrometry quality control analytical spike recovery for arsenic was below control limits. The arsenic result for this one soil sample was qualified as estimated (*J*).

Accuracy

The accuracy of the analytical results is evaluated in the following sections in terms of analytical bias (matrix spike, standard reference material [SRM], and laboratory control sample [LCS] recoveries) and precision (duplicate sample analyses).

Matrix Spike Recoveries

The recoveries reported by the laboratory for matrix spike and duplicate matrix spike analyses, and the frequency of analysis, met the laboratory's criteria for acceptable performance, with the exception of the recovery of aluminum in surface water sample delivery group (SDG) K2106565, which exceeded the control limit. All associated aluminum results were qualified as estimated (*J*).

Standard Reference Material Sample Recoveries

The recoveries reported by the laboratory for vegetation SRM analyses, and the frequency of analysis, met the laboratory's criteria for acceptable performance, with the following exceptions. The SRM recoveries from SRM Moss M3 (1136) for zinc in SDGs 110601 and 110701 and for aluminum in SDGs 110601, 110701, and 110801 exceeded control limits. Associated sample results were qualified as estimated (*J*). The SRM recoveries from SRM Moss M3 (1136) for lead in SDGs 110601 and 110701 and the SRM recovery from SRM Tomato Leaf (NIST 1573) for zinc in SDG 110701 exceeded control limits, but data qualification was not required since there was no data of a similar matrix and/or analyte associated with these SRMs.

Laboratory Control Sample Recoveries

The recoveries reported by the laboratory for all LCS, and the frequency of analysis, met the laboratory's criteria for acceptable performance.

Precision

Results for all duplicate sample analyses and the frequency of analysis met the laboratory's criteria for acceptable performance, with the following exception for soil samples. The duplicate relative percent difference for lead in "MS-" samples in SDG K2106399 exceeded control limits. All associated lead results in "MS-" samples were qualified as estimated. The

relative percent difference for lead in the pair of duplicate samples for “RS-” and “RF-” samples in SDG K2106399 was in control, and no qualification of “RS-” or “RF-” samples was required.

Field Quality Control Sample

Field quality control samples consisted of field duplicate samples, filter blank samples (to assess ambient dust levels), equipment rinsate blanks, and distilled water blanks. Three zinc, one lead, and five iron results in surface water were restated as undetected (*U*) because of detection of these metals in field blanks. The precision of all target analytes detected in the field duplicates was acceptable.